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Nebula ♅ I, 43 *Virginis*. By Professor Kavasjee D. Naegamvala.

The nebula was photographed on three successive nights (April 16, 17, and 18, 1896) with exposures ranging from one hour to two hours in the principal focus of a 16½in. reflector of 122 inches focal length.

The nebula is No. 4,594 in the *New General Catalogue*, and is described as "remarkable, very bright, very large, extremely extended, position-angle 92°, very suddenly much brighter in the middle with a nucleus." It is engraved in the *Philosophical Transactions for* 1833, plate xiv. fig. 50, and also in *Mem.R.A.S.* vol. xxxvi. plate v. fig. 22.

Sir John Herschel, in his "Observations of Nebulæ and Clusters of Stars" (*P. T.* 1833), remarks that "there is a faint diffused oval light all about it," and he is "almost positive that there is a dark interval or stratum separating the nucleus and general mass of the nebula from the light above." Mr. Lassell (*Mem.R.A.S.* xxxvi) with his much larger instrument describes it as a "long spindle-shaped nebula, with a dark band through its entire length." He, however, does not seem to have noticed the nucleus.

Of the two drawings, that of Sir J. Herschel much more resembles the photographs. The photograph taken 1896 April 18, distinctly showed that the nebula was *elliptical* with its plane highly inclined to the line of sight. (This plate was unfortunately destroyed during the final washing.) The nucleus is of a starry character, and much more pronounced than in Sir J. Herschel's drawing.

I hope to submit to the Society a photograph of the nebula at an early date.

May, 1897.

The Effect of the General Illumination of the Sky on the Brightness of Field at the Focus of a Telescope. By F. L. O. Wadsworth.

(*Communicated by the Secretaries.*)

The investigations of Lord Rayleigh have shown that the general illumination of the sky is probably due to light scattered by small (*i.e.* small in comparison with the wave-length of light) particles in our atmosphere, and that the intensity of the light so scattered varies inversely as the fourth power of the wave-length. It seems pretty certain that these particles are present in nearly, if not quite as great quantities, in the upper regions of the atmosphere as in the lower strata, and that they consequently cannot

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be of an aqueous origin. The majority of them being at a considerable distance above the surface of the earth, the scattered light which ultimately reaches the eye after repeated changes of direction is of plane wave front, and the general illumination is consequently of the same character as would be produced by a distant uniformly luminous surface of infinite extent. The illumination at any point p, which is the same as that at any other point in the focal field of a telescope, due to such a surface, is, as is well known,

$$\mathrm{I}_p = \int_\infty\int_\infty \mathrm{I}\,d\xi\,d\eta = \int_\infty\int_\infty \mathrm{I}\,dx'\,dy' \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (1)$$

where I is the illumination due to a single point s in the surface; $\xi\,\eta$, the coordinates of the point p, referred to the geometrical image of s, as origin; and conversely x', y', the coordinates of s, referred to the intersection of the optical axis through p, with the surface in which s is situated. The general principle of energy requires that the value of (1) should be equal simply to A, the area of the aperture of the telescope, when the apparent brightness of the surface is unity, or to k A when the apparent brightness is k. A general analytical proof has also been given by Stokes.[*] It follows, therefore, that the intensity of illumination of the focal field of a telescope, due to the light of the sky, is simply proportional to the area of the telescope aperture, and entirely independent of the focal length of the latter. In the theory of astronomical and astrophysical instruments, particularly those intended for photographic and spectrographic work, in which the greatest possible contrast between the field and the image of the body dealt with is desired, this is a point of great importance, which, strangely enough, has been hitherto entirely overlooked by all writers on the subject whose papers are accessible to me.[†] Some, indeed, have been led to very erroneous conclusions in regard to the form and size of instrument best adapted to particular purposes by a neglect of this relation between aperture and brightness of field. It has, therefore, seemed to me to be worth while to rediscuss somewhat at length the conditions of maximum efficiency in astro-photo-spectro-graphic work. The discussion as regards the purely astro-photographic side of the question is briefly outlined in the current (July?) number of *Knowledge*, "On the Conditions which Determine the Limiting Time of Exposure of Photographic Plates in Astronomical Photography," and will be found more fully developed, from a mathematical side, in the next (August) number of the *Astrophysical Journal*, "On the Conditions of Maximum Efficiency in

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[*] *Trans. Roy. Soc. Edin.* vol. xx. p. 317, 1853. See also "Wave Theory," *Enc. Brit.* vol. xxiv. § 11.

[†] The importance of this point in the case of photographic work is enhanced by the character of the sky illumination, which, owing to its varying as the fourth power of the wave-length, has a much greater effect on the photographic plate than on the eye.

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Astro-Photographic Work," in which questions relating to astrophysical work, particularly stellar and nebular spectrography and coronal photography, both during and without an eclipse, are also taken up. Without entering at length into the argument here, the more important conclusions which have been reached may be summed up as follows:—

I. The absolute intensity of the image of a celestial object, and, therefore, the absolute photographic light action (product of intensity by time) for a given time of exposure, will vary, (1) for extended sources as the square of the angular aperture only, (2) for point sources as the product of the square of the angular aperture times the square of the linear aperture.

II. The relative intensity of the image with respect to the field (contrast) for any celestial object not very near the horizon, will depend upon (1) the brightness of the sky at the time; (2) the efficiency of the image-forming lens as regards perfection of figure, nature and curvature of surfaces, &c.; and (3) upon the square of the linear aperture. If the objectives are good, the sky effect (1) and (3) are the most important.

III. For faint extended objects such as nebulæ, irresolvable star clouds, &c., in which we have to deal with the delineation of a surface rather than with individual points, this contrast can only be increased by decreasing the focal length. When the sky effect (1) and (3) is predominant it will vary inversely as the square of the latter quantity.

IV. For point sources the contrast can only be increased by increasing the angular aperture. Under the same conditions as in III, it will vary directly as the square of the angular aperture.

V. It is the degree of contrast, and not size of objective (except in so far as this latter influences the contrast) that determines the limiting magnitude of the faintest object that can be photographed. This limiting magnitude for stars depends therefore only on the angular aperture of the instrument, and for nebulæ only on the focal length.

VI. The time of exposure also depends very largely on the contrast between image and field, and not on the absolute intensity of the former. If the development could be suited in every case to the exposure, the time of the latter necessary to obtain any given degree of detail would vary inversely as the contrast within a wide range of photographic light action.

VII. In the problem of photographing the corona without an eclipse, the general conclusion in III is modified to some extent by the increased brightness and increased whiteness of the sky near the Sun, due probably to the presence of water vapour in the lower strata of our atmosphere. It seems, however, certain that a great advantage will result from using an image-forming lens of very small linear aperture and very short focal length for this purpose. Those who have used pin holes have been right in so far as a small linear aperture is concerned, but wrong in so far as they have placed the plate at a distance from the opening.

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VIII. For nebular spectrographic work the integrating spectrograph (one in which the image-forming or condensing lens is of zero dimensions), is the best possible form for securing a maximum contrast.

IX. In stellar spectrographic as well as in stellar photographic work, the "condensing" (telescope) objective should have the largest possible angular aperture.*

X. As regards the influence of the character of the objective (II (2)) upon the illumination of the field, the refractor seems to have a decided advantage. The angular aperture of the latter should not, however, be greater than 1-5. To photograph the very faintest star (beyond 17th magnitude) a reflector of the largest possible angular aperture, 1-3 or 1-2 if possible, is the only instrument that can be used. For stellar spectrographic work, in which only a small field is required, the reflector of large angular aperture is greatly superior to the refractor.†

Yerkes Observatory:
1897 *June* 3.

A Note on Spider Lines. By F. L. O. Wadsworth, Astrophysicist, Yerkes Observatory.

(*Communicated by the Secretaries.*)

Apropos of the present discussion on the straightness of spider lines—see paper by Professor Turner in the last (April) number of the *Monthly Notices*—it may be well to point out that whether such an effect has ever been observed or not, it would be well to guard against its possible occurrence by using for the cross wires in our instruments something of a more reliable and permanent nature than the usual spider web. This, although very fine and strong, has so many and such grave disadvantages as to make one wonder how it has ever been tolerated as long as it has. Formerly perhaps it might have been said that there was no thoroughly satisfactory substitute; even the finest metal wires prepared by the so-called Wollaston process being too coarse, and silk having the same disadvantages as spider line itself in the way of hygroscopicity and semi-translucency. Now, however, the invention of the quartz fibre by Boys has provided us with something

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* In connection with this point see also my paper, "General Conditions respecting the Design of Astronomical Spectroscopes," in the first number of the *Astrophysical Journal*, Jan. 1895, p. 52 (particularly pp. 70–71).

† For other advantages of the reflector see also paper by Professor Hale in a recent number of the *Astrophysical Journal* (Feb. 1897, p. 119), and various papers by the writer in the *Phil. Mag.* (vol. xxxviii. pp. 137 and 337), *Astronomy and Astrophysics* (vol. xiii. p. 835), and the *Astrophysical Journal* (vol. i. p. 232; vol. ii. p. 370; vol. iii. p. 169 [particularly pp. 182 and 183]; vol. iii. p. 347; &c.).